A product-technology portfolio alignment approach for food industry: A multi-criteria decision making with z-numbers

Garousi Mokhtarzadeh, N., Amoozad Mahdiraji, H., Jafari-Sadeghi, V., Soltani, A. & Abbasi Kamardi, A.

Original citation & hyperlink:
Garousi Mokhtarzadeh, N, Amoozad Mahdiraji, H, Jafari-Sadeghi, V, Soltani, A & Abbasi Kamardi, A 2020, 'A product-technology portfolio alignment approach for food industry: A multi-criteria decision making with z-numbers', British Food Journal, vol. (In-Press), pp. (In-Press).
https://dx.doi.org/10.1108/BFJ-02-2020-0115

DOI 10.1108/BFJ-02-2020-0115
ISSN 0007-070X

Publisher: Emerald

A Product-Technology Portfolio Alignment Approach for Food Industry: A Multi-Criteria Decision Making with Z-numbers

Abstract

Purpose. To design a novel hybrid approach to illustrate a reciprocal alignment to integrate future products and technologies. This mixed qualitative-quantitative method aims to optimize the final product portfolio and production technologies alignment in the food industry.

Design. A list of products and technologies is extracted and evaluated by experts employing Market Attractiveness and Ease of Implementations Matrix (MA-EI) for products and Attractiveness and technological Capability Matrix (A-C) for technologies. Weights of high-scored alternatives are attained applying the Z-number extension of Best Worst Method (ZBWM). After the Product-Technology matrix is formed and the alignment scores of each pair are determined by experts. Subsequently, final scores are computed and a framework is proposed by electing high-ranked products and technology of each cluster to form the aligned product and technology portfolios of a food and hygiene industry company.

Finding. By employing an uncertain multi-criteria decision-making approach besides product and technology matrices in a food industry corporation, among 40 technology and product, 13 products by 6 technologies are proposed. Thus, only six technology are necessary to manufacture the highly important and effective products.

Originality. The combination of product and technology analysis matrixes with an uncertain decision-making approach is considered as a novel approach in this research. Moreover, the distinctness between the present study and other researches is the concurrent unified aspect of product portfolio and technology optimization and its implementation in the planning discussion, especially in the food industry.

Keywords. Product-Technology Alignment; Product and Technology Portfolio; Technology Planning; ZBWM; Food Industry.

1. Introduction

Considering the pressure of the competitive environment, the pace of technology growth and shrinking product life cycles, firms are forced to set their product and technology portfolios interactively, which is usually done by adapting the technology road mapping approach. In this case, the alignment is a key communication channel between developing a product portfolio and a technology portfolio (Eppinger et al, 1990). The ability to adapt to dynamic market conditions and manage the ever-increasing variety of products, unpredictable production volumes, the rapid introduction of new products and emerging production technologies is a competitive advantage in today's environment (Andersen et al, 2018; Jafari Sadeghi, Nkongolo-Bakenda, et al. 2019). If technology planning is applied precisely and well-timed, the development process will be facilitated (Arasti & Jokar, 2015). Studies indicate that the number of new products has heightened by 34% from 1998 to 2004 (B.Kahn, 2014), product variegation has been doubled from 1997 to 2012 and the product life cycle has been diminished by about 25% (Andersen et al, 2018). Researches have also demonstrated that more than 86% of products fail in the product development process (Barczak et al, 2009). Moreover, only 59% of new commercial products succeed after launching. Besides, from the viewpoint of profitability, 54% of them are favorable (Kahn, 2014).

Notably, the complication of the product portfolio will motivate greater profits if it is managed effectively. Broadening the number of new products puts more tension on product planning by imposing higher production costs, lowering the profit margin (Kahn, 2014), flourishing costs from the exponential growth of entanglement, preventing from the profit of scale, inventory imbalances and jeopardizing production and distribution processes (Sadeghi, 2009). Introducing new products and rising product diversification have precipitate frequent changes in the production system, which are often expensive and time-consuming (Mokhtarzadeh et al, 2018; Rösiö & Bruch, 2018; Bruch & Bellgran, 2014). In process industries such as chemical or food industries, product innovation is the outcome of process innovation (Hullova et al, 2016). Firms in these industries require modifying production technologies for developing new products, providing opportunities for developing their production systems (Bruch & Bellgran, 2014; Lager & Rennard, 2014; Jafari-Sadeghi, 2019). In this regard, new approaches insist on the strategic alignment of production systems and technologies portfolio with product portfolio (Bruch & Bellgran, 2014; Lager & Rennard, 2014).

Numerous studies have investigated the product portfolio optimization by abundant methods such as Multi-Criteria Decision Making (MCDM), Multi-Objective Decision Making (MODM), Neural Networks (NN), Metaheuristic Algorithms, and Artificial Intelligence (AI). As an illustration, Khorshidian et al. (2019) have employed a bi-objective model, a hybrid of the improved version of the augmented e-constraint method (AUGMECON2) and TOPSIS to select the effective category of products and transportation planning (Khorshidian et al, 2019). Goli et al. (2019) have applied Two robust counterpart formulation for multi-objective product portfolio problems to minimize risk and maximize return in the dairy industry (Goli et al., 2019). Myorda et al. (2018) have focused on portfolio optimization through substitution and standardization techniques (Myrodia et al, 2018). Jiang et al. (2019) proposed a multi-objective optimization method of value recovery to the remanufacturing of End- of- Life product (Jiang et al., 2019). Furthermore, alongside product portfolio, some of the researches have surveyed technology alignment aspects e.g. alignment of technology and business strategy (McAdam, Bititci and Galbraith, 2017) and technology alignment in the presence of regulatory changes (Nair and Dreyfus, 2018).

Therefore, new approaches insist on the strategic alignment of production systems and technologies portfolio with product portfolio (Bruch & Bellgran, 2014; Lager & Rennard, 2014). Qualitative methods lack to evaluate and sort this alignment appropriately. Furthermore, the quantitative methods for this alignment have not been studied sufficiently, yet. In this regard, in our proposed method a novel decision-making approach has been demonstrated to align Product-Technology portfolios. Moreover, due to qualitative criteria dealing with the alignment challenge, alongside with the uncertainty relevant to decision-making processes, deterministic methods are not reliable. Accordingly, the authors designed a Z-number based method to consider existing uncertainty.

In this paper, the product and technology have been considered at the same time. Hence, a list of products and technologies are extracted. Obtained products and technologies are evaluated by experts employing Market Attractiveness and Ease of Implementations Matrix for products and Attractiveness and Technological Capability Matrix for technologies. Weights of high-scored alternatives are attained applying the Z-number extension of Best Worst Method (ZBWM). Z- numbers assist this research to deal with uncertainty. In the following, the product- technology matrix is formed and the alignment scores of each pair are determined by experts. Subsequently, final scores of the product and technology are computed and a framework is proposed by electing high-ranked products and technology of each cluster to form the aligned product and technology portfolios. Our proposed approach has been applied in a food industry case and productive results were emanated.

The rest of this paper is organized as follows. First, the basic concepts relevant to this research are presented and the previous related studies are investigated. Next, the methodology and the proposed hybrid process of this research are described. Subsequently, the food industry case is introduced and the results of employing the proposed method are explained. Eventually, the implications, limitations and the conclusion are discussed.

2. Theoretical Foundation and Previous Researches

Ability to adapt to dynamic market circumstances and increasing diversify management, unpredictable production volume, hasty presentation of new products and production technologies are often appearing as a key competitive advantage in a present production environment (Andersen et al, 2018). In contemporary markets, manufacturing companies are under stress to repeatedly propose disparate and new products to market over short periods. Product planning is found on the firm's goals, potentials, and limitations. Product portfolio planning is a field of production and technology management and one of the remarkable prerequisites for flexible and customized mass production (Arasti & Jokar, 2015). In the current competitive situation, one of the vital concerns of executives is to determine what product should be marketed. Businesses are progressively looking to widen product range and deliver them accurately as much as possible to distinctive segments of the market. Hence, the products in the manufacturer's product portfolio are more appealing to people (Abadi, 2014). Likewise, deciding on the optimal combination of product features is an influential decision. The optimum product portfolio is a consolidation of products to be offered that will maximize market share while taking into account production costs (Sadeghi, 2009).

On the other hand, technology planning is an essential part of any firm's planning system business which must be approached both at the corporate and business level (Khalil, 2000). By appearing novel technologies such as the Internet of Things in the distinct parts of the value chain, firms are compelled to concentrate technology planning to enhance the effectiveness and efficiency (Ramundo et al, 2016). Technology is an integral part of any business and an effective and empowering factor to strengthen company performance and productivity (Jafari Sadeghi & Biancone, 2017a). The purpose of the technology strategy concept is to provide a broad and comprehensive approach to achieve organizational goals through the benefits of technological capabilities in a competitive environment. This strategy should state guidelines for the selection and implementation of particular actions. Other results of this category include guiding the type and structure of the technology portfolio (Mahdiraji et al, 2014; Moon & Lee, 2017), intended applications and methods for generating revenue from the usage. The selection of required technology based on the firm's competitive strategy is one of the strategic decisions in the technology planning process. Various tools and methods have been developed for technology selection. Many firms are trying to manage their technology by integrating technology and business into a proper framework and align technology and institutional readiness (Webster & Gardner, 2019). Constant attention to the purposeful use of technology strategy is constitutional for companies since it is the singular way that they can accomplish growth and development by technologies (Stacey & Ashton, 1990).

2.1. Product-Technology Alignment

A product- technology alignment means the two-way connection between product and process innovations. This is borrowed from the science of physics, which means "a relationship or situation in which two or more distinct things reinforce or emphasize each other's characteristics" (Hullova et al, 2016). A firm demands a community, understanding of how production can support its business. Assessment of how existing processes fit the desires of the organization's current market and picking the right process to meet future needs is a noteworthy production responsibility in the strategy discussion of the company (Hill et al, 1998; Jafari Sadeghi et al, 2014). Manufacturing companies should perpetually develop and materialize technologies for enhancing their manufacturing processes and equipment and try to acquire unique production systems (Jafari Sadeghi & Biancone, 2018; Bello-pintado et al, 2018). Regarding the high cost of investing in restored production equipment, abounding manufacturing firms avoid generating new products so as not to disrupt their existing production machinery (Rösiö & Bruch, 2018). Production system development refers to a level above the process level which includes all elements of the production system for instance technology (Bruch & Bellgran, 2014). Revived production technology can advance new product performance and create a competitive advantage (Mahdiraji et al, 2012; Ahlskog et al, 2017; Jafari Sadeghi & Biancone, 2017b; Mahmoudi et al, 2018).

Expressly in the food industry, the development of new products is often a technology-driven process which signifies the role of technology. Nowadays, food manufactures must provide high- quality, convenient, healthy and sustainable food found on customers' needs and tastes. To face these remarkable challenges, firms must concentrate on technology planning (Esbjerg et al, 2016). Although the impact of production technologies on production performance has received a great deal of attention in operations management literature, the enactment of technology and knowledge which has been impressive in adoption performance was not surveyed sufficiently (Bello-pintado et al, 2018, Jafari Sadeghi, Nkongolo-Bakenda, et al 2019; Rezaei, et al, 2020). Diversified range and types of alignment can occur between the product and process innovation which is elaborated in Table 1.

Please insert Table 1 here

The merge of product portfolio and relevant production systems requires the investigation of future needs in the early stages of the product development process. A basic model of this integrated portfolio approach is amplified in Figure 1. This is an optimal approach for planning.

Please insert Figure 1 here

The main idea of the model of Figure 1 is that the benefits of a portfolio are worth the effort of collecting compatible data and building trust and commitment in the organization. The preeminent goal is to hit the more productive production systems, which means condescend production costs and stepped up profitability. The approach will also persuade a strategy to better balance market-based and production-based product development (Bruch & Bellgran, 2014; Mahdiraji et al, 2015).

Abundant analogous issues have been researched being product portfolio or technology portfolio optimization e.g. by Cooper et al. (1997), Cooper et al. (2001), Jolly (2003), Zhang & Jiao (2005), Sadeghi (2009), Sadeghian (2011), Fadaee (2015) and Cooper et al. (2016). Nevertheless, previous studies have been restricted to optimizing a portfolio of products or technologies and have not centralized on consolidating the two at the same time as Bruch and Bellgran (2014). Next in order, the alignment of these two portfolios is a fully novel topic that researchers have realized, not long ago (Razavi Hajiagha et al, 2015; Potstada et al, 2016; Hullova et al, 2016;).

The distinctness between the present study and other researches in these two fields (including product or technology portfolio and integrated planning and alignment of product and technology portfolio) is the concurrent unified aspect at product portfolio and technology optimization and its implementation in planning discussion. The similarity of this research to other studies is applying the initial concept of primary sifting of possible alternatives of product and technology portfolio. This method is alike with enforced technique in Reckitt and Coleman Company (Cooper et al, 1997) for technology and identical with Jolly (2003) for products. Besides, Lager (2002), Bruch and Bellgran (2014) and Hullova et al. (2016) have stressed on allied and synchronic planning of product and technology. Furthermore, the model of Hullova et al. (2016) has been applied in this paper. Strategic alignment of technology has also been proposed recently (Hajiagha et al, 2015a,b; Bernat & Karabag, 2019).

2.2. Market Attractiveness vs Ease of Implementation Matrix

This matrix (Figure 2) is used to evaluate new product development projects and has two dimensions including market attractiveness (context) and ease of implementation. The matrix has been developed by Rekitt & Coleman to evaluate new product development projects. This matrix is a similar type of matrix to the Boston Consultancy Group matrix, except that its two dimensions represent market/background attractiveness (from low to high) and ease of implementation (low to high), which are both risky and rewarding. In this matrix, the attractiveness of the market and the simplicity of implementation include five separate scoring criteria. The criteria for each dimension are introduced following the matrix (Cooper et al, 2016). This method has been used in the present study to evaluate potential product development projects.

Please insert Figure 2 here

Each dimension of this matrix is assessed by various criteria. These criteria are elaborated into two sections including market attractiveness and ease of implementation. For market attractiveness, five sub-criteria are considerable including Attractiveness for the customer (C_{MA1}), Product advantage (C_{MA2}), Sustainability of the advantage (C_{MA3}), International field (C_{MA4}) and Financial attractiveness (C_{MA5}). On the other hand, for ease of implementation, five sub-criteria are considerable including Technical feasibility (C_{EI1}), Lack of development challenges (C_{EI2}), Packaging (C_{EI3}), Coordination with company production capabilities (C_{EI4}) and Distribution (C_{EI5}).

2.3. Technology Attractiveness vs Firm's Capability Matrix

Various tools and methods have been developed to select technology. Numerous companies are trying to integrate technology and business management in the form of a suitable framework. Continuous attention to the targeted use of technology strategy for companies is necessary because only In this way, they can use technology to achieve profitable growth and development (Stacey & Ashton, 1990). Due to the great impact of technology on the company's competitiveness and the costs and risks associated with it, some of the technology management processes are challenged. Technology selection is one of the most challenging processes of technology portfolio management. The connection between strategy and technology has become a contentious issue in recent years, beginning with an article by the Stanford Research Institute entitled "Technology Portfolio Analysis." In this paper, Technology Attractiveness vs Firm's capability matrix (Figure 3) is applied to assess new technology development projects and appointments and consists of two dimensions of technology attractiveness and capability.

Please insert Figure 3 here

Each dimension of this matrix is analyzed by varied criteria. These criteria are divided into two sections including attractiveness criteria and capability criteria as follows. For attractiveness criteria, five sub-criteria are performable including Accessible Market Size by Technology (C_{at1}), Accessible Application Range by Technology (C_{at2}), Technology performance compared to other alternatives (C_{at3}), Technology impact on competitive issues (C_{at4}) and Technology transfer capabilities to other units (C_{at5}). On the other hand, for capability criteria, five sub-criteria are performable including Communication with the core Business (C_{ca1}), the accumulated knowledge in the field (C_{ca2}), Technology exploitation capacity (C_{ca3}), Financial capacity (C_{ca4}) and Abilities of the development team (C_{ca5}).

2.4. Z-numbers Best Worst Method

BWM is a multi-criteria decision-making technique for extracting the weights of the criteria which was first introduced by Rezaei in 2015 (Rezaei, 2015). Numerous approaches to BWM have been proposed divided into groups of certain and uncertain approaches. For certain circumstances, Nonlinear BWM (Rezaei, 2015), Linear BWM (Rezaei, 2016), Euclidean BWM (Kocak, Caglar & Oztas, 2018) and Multiplicative BWM (Brunelli & Rezaei, 2019) are presented. On the other hand, for uncertain conditions, Interval- Grey BWM (Rezaei, 2016), Fuzzy BWM (Guo & Zhao, 2017), Z-numbers BWM (Aboutorab et al, 2018), Intuitionistic Fuzzy BWM (Mou et al, 2016) and Bayesian BWM (Mohammadi & Rezaei, 2019) are designed and evolved.

Z-number is related to a random variable which is consisting of fuzzy number order pairs *(A, B)*. *A* refers to the value of the random variable and *B* indicates the reliability of the value (Wang et al, 2017; Kang et al, 2012). Indeed, ZBWM is a combination of Z-numbers and BWM. Remark that less pairwise comparison, higher consistency, the power to serve uncertainty and power to be operated for Big data are the main specifications of this method. Nonetheless, the subjectivity issue of the fuzzy part during the concept translation process is considered as the main limitation of this approach (Aboutorab et al, 2018). Steps of ZBWM are described in the coming (Aboutorab et al, 2018).

Step 1. A criteria decision matrix is formed: $\{C_1, C_2 ..., C_n)$.

Step 2. The best criteria (C_B) and the worst criteria (C_W) are determined by experts.

Step 3. Preferences and certainties of the best criteria over other criteria are determined by experts applying z-numbers reference: $\tilde{A}_B = \{\tilde{a}_{B1}, \tilde{a}_{B2} \dots, \tilde{a}_{Bn}\}$ applying Table 6.

Please insert Table 2 here

Step 4. Preference of other criteria over the worst criteria is determined by experts applying z-numbers reference: $\tilde{A}_W = \{\tilde{a}_{1W}, \tilde{a}_{2W} \dots, \tilde{a}_{nW}\}$ applying Table 2. Note that, each triangular fuzzy number (TFN) consists of three sections (l) for lower bound, (u) for upper bound and (m) for middle value.

Step 5. Optimal fuzzy weights ($\{\widetilde{W}_1^*, \widetilde{W}_2^* \dots, \widetilde{W}_n^*\}$) are computed by solving (1).

$$
\begin{aligned}
&\min k \\
&\text{s.t:} \\
&\left|\frac{(l_B^W,\ m_B^W, u_B^W)}{(l_j^W,\ m_j^W, u_j^W)} - (l_{Bj}, m_{Bj}, u_{Bj})\right| \le (k^*, k^*, k^*) \\
&\left|\frac{(l_j^W,\ m_j^W, u_j^W)}{(l_W^W,\ m_W^W, u_W^W)} - (l_{jW}, m_{jW}, u_{jW})\right| \le (k^*, k^*, k^*) \\
&\sum_{j=1}^{n} R\left(\widetilde{W}_j\right) = 1 \\
&l_j^W \le m_j^W \le\ u_j^W \\
&l_j^W \ge 0 \\
&j = 1, 2 \dots, n
\end{aligned}
\tag{1}
$$

Notice that for related TFN values$\widetilde{W}_B = (l_B^W,\ m_B^W, u_B^W)$, $\widetilde{W}_j = (l_j^W,\ m_j^W, u_j^W)$, $\widetilde{W}_W = (l_W^W, m_W^W, u_W^W)$, $\tilde{a}_{Bj} = (l_{Bj}, m_{Bj}, u_{Bj})$ and $\tilde{a}_{jW} = (l_{jW}, m_{jW}, u_{jW})$.

Step 6. Consistency Rate (CR) of the experts' opinion is calculated by (2). The high values of this criteria are not acceptable.

$$CR = \frac{\xi^*}{CI} \tag{2}$$

Where the Consistency Index (CI) is determined by Table 3.

Please insert Table 3 here

Step 7. The arithmetic average of each bound is calculated to integrate experts' opinions.

Step 8. Crisp values of the weights ($R(\widetilde{W}_j)$) are extracted by (3).

$$R(\widetilde{W}_j) = \frac{l_j + 4m_j + u_j}{6} \tag{3}$$

3. Methodology

The following figure displays the implementation steps of the present study. Note that, in our proposed method a novel decision-making approach has been demonstrated to align Product-Technology portfolios. Due to qualitative criteria dealing with the alignment challenge, alongside with the uncertainty relevant to decision-making processes, deterministic methods are not reliable. Thus, to find the most optimal Product-Technology alignment, uncertain MCDM based methods are employed. These methods do not require numeric data and generate the evaluation and relationship of products and technologies by the expert's opinion.

Please insert Figure 4 here

Stage 1. At this stage, a list of available potential manufacturing products and technologies of the industry is extracted by searching the relevant databases and reviewing top articles and international companies, as well as reading various catalogs and blogs.

Stage 2. Product and technologies identified in stage 1, are shared with experts together with attached questionnaires and related information to be evaluated. Assessments are performed employing Market Attractiveness vs Ease of Implementation Matrix for products (Cooper et al, 2016) and Attractiveness vs Capability Matrix for technologies (Stacey & Ashton, 1990). The score of each product or technology is considered in each criterion. The average scores given by the experts are calculated and finally, the average scores will be deliberated as the Cartesian coordinates of each alternative (Mokhtarzadeh et al, 2018).

Stage 3. Weights of the elected products and technologies are extracted by experts' opinions employing the ZBWM model (Aboutorab et al, 2018) and LINGO software.

Stage 4. Product- technology matrix is built found on the nominated product and technologies of stage 2 and the extracted weights of stage 3 (Mokhtarzadeh et al, 2018).

Stage 5. Alignment scores of each product- technology pair is attained by a questionnaire placed on the alignment level. Note that, for Reciprocal, Product- Sequential, Process-Sequential, Product- Amensalism, Process- Amensalism, Product- Pooled and Process- Pooled, scores from 7 to 1 are employed, relatively (Amoozad Mahdiraji et al, 2018).

Stage 6. Final scores of each product and technology are obtained by the alignment scores of stage 5 and the computed weights of stage 3. Consequently, high-scored products and high-scored technology in each field are selected to construct the portfolios of the company.

$$PS = \sum_{i=1}^{n} \left(As * w_{p_i}\right) \tag{4}$$

$$TS = \sum_{i=1}^{m} (As * w_{ti}) \tag{5}$$

Note that in Eq. (4) and (5), *PS* and *TS* show the total Product Score and total Technology Score (Razavi et al, 2015). *As* is the Alignment Score and w_{p_i}/ w_{ti} are the extracted weights of the product/ technology resulted from ZBWM (Aboutorab et al, 2018), respectively.

4. Case Study and Findings

Khorramshahr Oil Co., Ltd (KHOC), with over 75 years of experience as a pioneer in the food and hygiene industries, is the first manufacturer of edible vegetable oils, standard olive oil and detergent oils in the domestic market. This company owns the most modern oilseed factory in Iran. The statistical population of this study is a group of experts and managers of distinctive units of KHOC. The reason for their selection is their high expertise and experience in this field. In light of the usefulness of the results of the research for this organization, the necessary cooperation has been made by them to advance the current study. The experts of the research in which their opinions are applied for initial screening of the products and technologies and performing ZBWM. Note that five groups of experts from different positions and different educational backgrounds participated in this research. Five experts with Ph.D. from the CEO group, four experts with Ph.D. from strategy department, five experts with Ph.D. from research and development department, five experts with MBA from the commercial department and three experts with MBA from manufacturing department (totally 20), cooperated.

In stage 1, potential products and technologies of the oil industry are identified. It is also worth noting that, given the variety of oils in terms of consumer recognition and range of use, they can be divided into four categories as follows.

- Normal with the main application in Cooking and Edible (Sunflower, Soy, Palm, Rapeseed, Canola, Corn, Olive, Pumice, Sesame).
- Economical with the main application in Cooking and Edible (Cottonseed, Rice Bran, Mustard, Safflower, Linseed, Cotton, Castor).
- Expensive with the main application in Medical and Hygienic (Almond, Peanut, Cashew, Pistachio, Walnut, Hazelnut, Avocado, Argan).
- Special with the main application in Medical and Hygienic (Coconut, Ambadi, Perilla, Macadamia, Tea Seed, Pine Seed, Purslane Seed, Grape Seed, Watermelon Seed, Pomegranate Seed).

The final list of KHOC products is provided after holding consultation meetings with experts. These products are signed as P_k in which *k* is a number from 1 to 40. They are anonymous to keep the company's trade secrets. In conjunction with products, a list of accessible technologies in 6 fields is offered, elaborated in Table 4.

Please insert Table 4 here

In stage 2, identified products and technologies of the previous stage are screened. For this purpose, each expert scores each product and technologies, based on 2-dimension matrixes of Figure 2 and Figure 3 by 9-point Likert Spectrum which is presented in Table 5 and Table 6.

Please insert Table 5 here

Note that, in Table 5, products with high market attractiveness were selected and highlighted. Consequently, 22 products from available options were considered as attractive products with scores higher than 4.5.

Please insert Table 6 here

Note that, in Table 6, technologies with high attractiveness were selected and highlighted. Accordingly, 24 technology from available options were considered as attractive technologies with scores higher than 4.5. Consequently, by computing the average of the experts' scores, Cartesian coordinates of the products and technology are found out which are depicted in Figure 5 and Figure 6.

Please insert Figure 5 here

Please insert Figure 6 here

Hence, the results of the experts' preferences and certainties found on the references in Table 2 are gathered. The model of (1) is formed and solved placed on this information and the optimal results are defuzzified by equation (3). The average optimal weights of selected products and technologies (including 22 product and 24 technology) are illustrated in Table 7.

Please insert Table 7 here

It is noticeable that the consistency rate of the experts' opinion is calculated by Eq.(2) based on Table 3. Note that all groups of experts received acceptable CI and CR after two rounds; hence, the results are valid and reliable. In stage 4, the Product- Technology Matrix is built by an average of experts' opinions found on the alignment scores which is detailed in Table 8.

Please insert Table 8 here

After forming a product- technology matrix, in stage 6 total scores of the alignments are computed by Eq. (4) and (5) regarding the obtained weights of Table 7. The results are elaborated in Table 9. Remark that, based upon ZBWM, product technology matrix, and experts' opinion, for degumming sector T_8, for neutralization T_{12}, for discoloration T_{19}, for disinfection T_{24}, for fire tube $T_{33,}$ and water waste treatment T_{35} are the most appropriate technologies to be considered. In products, P_9 to P_{13}, P_{15}, P_{16}, P_{20} to P_{23}, P_{28} and P_{29} are the most desirable products to be manufactured by the selected technologies.

Please insert Table 9 here

The selected technology portfolio is perfectly optimal. Besides, alignment scores express the high- complementary of the pairs. As an illustration, even though P_{13} has been chosen in the final portfolio, it has the lowest weight. This highlights the high technology alignment of P_{13} in comparison with other alternatives.

5. Discussion and Implication

Theoretical. Numerous studies have discussed the product portfolio and technology portfolio. In most studies, product portfolio optimization has not been performed by considering its alignment with technology. However, the alignment of them is highlighted which must be investigated, precisely. Our study has attempted to offer a novel framework for product-technology alignment. The alignment of product portfolio and technology portfolio and its immense significance have been addressed in many studies, especially in the literature of technology road mapping (e.g., Lee & Park, 2005; Phaal et al, 2004) and product development management (Closs et al, 2008). However, these researches mostly have addressed the issue in qualitative methods and there are little studies approached the case employing quantitative methods. Remark that our framework has been presented quantitatively. As our studied literature indicates, previous researches have not considered a quantitative approach based upon multiple criteria decision-making methods to attain this portfolio matrix. MCDM helps decision-makers to assess the problems involving multiple measures similar to this study (Kou et al. 2020). The authors have applied this capable method to promote decisions. BWM is an MCDM technique that is used in our research. It has been a favorite method since its introduction by Rezaei (Rezaei, 2015). Due to the high number of products and possible technologies, BWM can reduce the pair comparisons, remarkably. Therefore, as the significance of all products and technologies is not similar, our paper employed BWM to extract the weights. Besides, to bring the proposed method closer to the real environment, the z-number development of BWM has been used. Z- numbers can advance the reliability of the information by taking uncertainty into account (Zadeh, 2011). In other words, in a novel age, information deals with uncertainty and decisions are made found on this uncertain information. Thus, our research enhances the reliability of decision making by using z- numbers to define information.

Applicational. The rise of change in the food industry is significantly rising by the side of other industries. Firms are compelled to develop varied products to satisfy customers. Indeed, customers' tastes and needs are upgrading expeditiously and firms are forced to respond. To acknowledge nimbly, the alignment of technology and products is a critical necessity for firms. The authors have proposed a framework that can be employed to align the product and technologies. Hence it will raise the productivity and efficiency of the firms' process and this will lead to customer satisfaction. Furthermore, electing the wrong technology can make the firm to suffer from financial damages. To avoid this loss, we have recognized the highlighted products and technologies among various of them and planned applicably to align them. Therefore, our presented framework reduces the cost and risks of the decisions.

Managerial and Policy Making. Making a decision is a crucial role for managers. The future of a firm is based on these decisions. Thus, our study has aimed to develop a framework for managers to make appropriate decisions. Decisions are made placed on information considering various criteria. Our proposed method employed the Z-BWM technique to consider the uncertainty and conflict of the information. This framework can facilitate the task of managers in every type of decision. Specifically, our framework has been performed for the decision of product- technology alignment. The cost and risk of technology and product development have been escalated and become very challenging for firms (Biancone & Jafari Sadeghi, 2016). The result of our study aids the managers to select well-integrated portfolios with higher efficiency and effectiveness of the product and technology development process. The proposed method is not limited to the food industry. Our framework can conduct the policymakers of every industry to enhance the effect of their policies by making opportune decisions.

6. Conclusion and Future Recommendations

In this study, a framework has been proposed to optimize the alignment of future products and production technologies in a food industry company case study. To achieve this aim, numerous databases have been investigated and accessible products and technologies are nominated for building the company's portfolio by five groups of experts. Obtained products and technologies are assessed by experts applying Market Attractiveness vs Ease of Implementations Matrix for products and Attractiveness vs Capability Matrix for technologies. Moreover, ZBWM as a recent uncertain evaluating method has been employed to extract the weights of products and technologies. Subsequently, the alignment scores of the product- technology pairs have been gathered by experts' opinions and the product score and technology scores are calculated. The high- scored products and technologies are selected to form the portfolios of the company which deliberates the high- complementary of the products and technology.

This novelty of this study could be developed in future studies by employing new uncertain approaches such as hesitant fuzzy, intuitionistic fuzzy, interval fuzzy and interval-valued intuitionistic fuzzy. Furthermore, other weighing methods such as pairwise comparison, step-wise weight assessment ratio analysis and other types of BWM could be applied. Moreover, this framework is suggested to be performed in other industries in future studies.

7. References

Aboutorab, H., Saberi, M., Asadabadi, M.R., Hussain, O., Chang, E. (2018). ZBWM: The Z-number extension of Best Worst Method and its application for supplier development. *Expert Systems with Applications*, *107*, 115-125.

Ahlskog, M., Bruch, J., Jackson, M., (2017). “Knowledge Integration in Manufacturing Technology Development.” *Journal of Manufacturing Technology Management* 28(8), 1035–1054.

Amoozad Mahdiraji, H., Arzaghi, S., Stauskis, G., Zavadskas, E. (2018). A hybrid fuzzy BWM-COPRAS method for analyzing key factors of sustainable architecture. *Sustainability*, *10*(5), 16-26.

Andersen, A.L., Larsen, J.K., Brunoe, T.D., Nielsen, K., Christopher, K., (2018). “Critical Enablers of Changeable and Reconfigurable Manufacturing and Their Industrial Implementation.” *Journal of Manufacturing Technology Management* 29(6), 20-30.

Anderson, P., Tushman, M.L., (1991). “Managing Through Cycles of Technological Change.” *Research-Technology Management* 34(3), 26–31.

Arasti, A., Jokar, A., Karimpour. A., (2015). “Designing a Model for Integrated and Strategic Planning of Technology Groups.” *Journal of Technology Development Management, 1(2),* 9-48.

Aylen, J. (2013). “Open versus Closed Innovation: Development of the Wide Strip Mill for Steel in the United States during the 1920s.” Pp. 67–80 in *R and D Management*. Vol. 40.

Kahn, K.B., 2014. *Product Planning Essentials Second Edition*. 2nd ed. New York: Taylor and

Francis.
Barczak, G., Griffin, A., Kahn, K.B., (2009). “Perspective: Trends and Drivers of Success in NPD Practices: Results of the 2003 PDMA Best Practices Study.” *Journal of Product Innovation Management* 26(1), 3–23.
Bello-pintado, A., Teresa, G.M., Zouaghi, F., (2018). “Product / Process Definition, Technology Adoption, and Workforce Qualification : Impact on Performance.” *International Journal of Production Research* 7543(May), 1–17.
Bergfors, M.E., Larsson. A., (2009). “Product and Process Innovation in Process Industry: A New Perspective on Development.” *Journal of Strategy and Management* 2(3), 261–276.
Bernat, S., Karabag, S.F. (2019). Strategic alignment of technology: Organising for technology upgrading in emerging economy firms. *Technological Forecasting and Social Change*, *145*, 295-306.
Biancone, P.P. Jafari Sadeghi, V. (2016) Risk Management in Export Compliance: Concepts, Procedures, and Solutions. in V Cantino, P De Vincentiis & MG Racca (eds), *Risk management: Perspectives and open issues*. McGraw-Hill, pp. 64–78, International Conference on Risk Management, Turin, Italy, 5/05/16.
Bigliardi, B., Galati, F., (2013). “Innovation Trends in the Food Industry: The Case of Functional Foods.” *Trends in Food Science and Technology* 31(2), 118–129.
Bruch, J., Bellgran. M., (2014). “Integrated Portfolio Planning of Products and Production Systems.” *Journal of Manufacturing Technology Management* 25(2), 155–174.
Brunelli, M., Rezaei. J., (2019). “A Multiplicative Best – Worst Method for Multi-Criteria Decision Making.” *Operations Research Letters* 47(1),12–15.
Capon, N., Farley, J.U., Lehmann, D.R., Hulbert. J.M. (1992). “Profiles of Product Innovators Among Large U.S. Manufacturers.” *Management Science* 38(2), 157–69.
Closs, D.J., Jacobs, M.A., Swink, M., Webb, G.S. (2008). Toward a theory of competencies for the management of product complexity: six case studies. *Journal of Operations Management*, 26(5), 590-610.
Cooper, R., Scott E., Elko, K., (2001). “Portfolio Management for New Product Development: Results of an Industry Practices Study.” *R and D Management* 31(4), 361–380.
Cooper, R.G., Scott J.E., Elko, J.K., (1997). “Portfolio Management in New Product Development: Lessons from the Leaders-II.” *Research-Technology Management* 40(6), 43–52.
Cooper, R.G., Scott J. Edgett, E.J., Kleinschmidt, R.G.. Cooper, S.J., Edgett, E.J., Kleinschmidt, P. (2016). “Portfolio Management in New Product Development : Lessons from the Leaders — I Portfolio Management in New Product Development : Lessons from the Leaders I.” *Research-Technology Management* 6308(June).
Eppinger, S.D., Fine, C.H., Ulrich, K.T., (1990). “Interdisciplinary Product Design Education.” *IEEE Transactions on Engineering Management* 37(4), 301–305.
Esbjerg, L., Burt, S., Pearse, H., & Glanz-Chanos, V. (2016). Retailers and technology-driven innovation in the food sector: caretakers of consumer interests or barriers to innovation?. *British Food Journal*, *118*(6), 1370-1383.
Fadaee, R. (2015). “Project Portfolio Selection Methods in Technology Development Projects.” 3(12), 1-10.
Farrukh, C., Phaal, R., Probert, D., (2003). “Technology Roadmapping : Linking Technology Resources into Business Planning.” *International Journal of Technology Management* 26(1), 2–19.
Goli, A., Zare, H. K., Tavakkoli-Moghaddam, R., & Sadeghieh, A. (2019). Hybrid artificial intelligence and robust optimization for a multi-objective product portfolio problem Case study: The dairy products industry. *Computers & Industrial Engineering*, *137*, 106090.
Guo, S., Zhao, H., (2017). “Fuzzy Best-Worst Multi-Criteria Decision-Making Method and Its Applications.” *Knowledge-Based Systems* 121, 23–31.

Hajiagha, S.H.R., Akrami, H., Hashemi, S.S., Amoozad Mahdiraji, H. (2015). An integer grey goal programming for project time, cost and quality trade-off. *Inzinerine Ekonomika*, *26*(1), 93-100.
Hajiagha, S.H.R., Hashemi, S.S., Mahdiraji, H.A., Azaddel, J. (2015). Multi-period data envelopment analysis based on Chebyshev inequality bounds. *Expert Systems with Applications*, *42*(21), 7759-7767.
Hullova, D., Trott, P., Simms, C.D., (2016). Uncovering the Reciprocal Complementarity between Product and Process Innovation. *Research Policy* 45(5), 929–40.
Jafari-Sadeghi, V. (2019) The motivational factors of business venturing: Opportunity versus necessity? A gendered perspective on European countries. *Journal of Business Research*. doi: 10.1016/j.jbusres.2019.09.058
Jafari-Sadeghi, V., Kimiagari, S. Biancone, P.P., (2020) 'Level of Education and Knowledge, Foresight Competency, and International Entrepreneurship: A Study of Human Capital Determinants in the European Countries', *European Business Review*, 32(2). doi: 10.1108/EBR-05-2018-0098.
Jafari Sadeghi, V., (2018) 'How does export compliance influence the internationalisation of firms: is it a threat or an opportunity?', *Journal of Global Entrepreneurship Research* 8(1), p. 3. doi: 10.1186/s40497-018-0089-3.
Jafari Sadeghi, V., Nkongolo-Bakenda, J.M., (2019) 'An institution-based view of international entrepreneurship: A comparison of context-based and universal determinants in developing and economically advanced countries', *International Business Review*. 28(6), p. 101588. doi: 10.1016/j.ibusrev.2019.101588.
Jafari Sadeghi, V., Biancone, P. (2019) 'International entrepreneurship by particular people "on their own terms": evidence of universal attributes of entrepreneurs in evolving economies', *International Journal of Entrepreneurship and Small Business*, 37(2), pp. 288–308. doi: 10.1504/IJESB.2019.100109.
Jafari Sadeghi, V., Biancone, P.P., (2017a) 'Exploring the Drivers of Gender Entrepreneurship: Focus on the motivational perspectives in USA, Italy and France', in Ratten, V. et al. (eds) *Gender and Family Entrepreneurship*. Routledge Taylor & Francis Group, pp. 124–141. Available at: https://www.routledge.com/Gender-and-Family-Entrepreneurship/Ratten-Ramadani-Dana-Hisrich-Ferreira/p/book/9781138228870.
Jafari Sadeghi, V., Biancone, P.P., (2017b) 'Shariah Compliant International Entrepreneurship: A Study of Islamic Finance in Europe', European Journal of Islamic Finance, (8), pp. 1–8. doi: 10.13135/2421-2172/2328.
Jafari Sadeghi, V., Biancone, P., (2018) 'How micro, small and medium-sized enterprises are driven outward the superior international trade performance? A multidimensional study on Italian food sector', Research in International Business and Finance. Elsevier, 45(October 2018), pp. 597–606. doi: 10.1016/j.ribaf.2017.07.136.
Jafari Sadeghi, V., Jashnsaz, A., Honari Chobar, M. (2014) 'Organisation's Conformity Assessment with Peter Senge's Learning Organisation Principles in Municipality of Saveh: A Case Study', Journal of Business and Management, 16(5), pp. 51–58. doi: 10.9790/487x-16555158.
Jolly, D. (2003). "The Issue of Weightings in Technology Portfolio Management." *Technovation* 23(5):383–91.
Kang, B., Wei, D., Li, Y., Deng, Y. (2012). Decision making using Z-numbers under uncertain environment. Journal of Computational Information systems, 8(7), 2807-2814.
Khalil, T. (2000). *Management of Technology : The Key to Competitiveness and Wealth Creation*. McGraw-Hill Education.

Khorshidian, H., Shirazi, M. A., & Ghomi, S. F. (2019). An intelligent truck scheduling and transportation planning optimization model for product portfolio in a cross-dock. *Journal of Intelligent Manufacturing*, *30*(1), 163-184.
Kocak, H., Caglar, A., Oztas, G.Z. (2018). Euclidean Best–Worst Method and Its Application. *International Journal of Information Technology & Decision Making*, *17*(05), 1587-1605.
Lager, T. (2002). "Product And Process Development Intensity In Process Industry: A Conceptual And Empirical Analysis Of The Allocation Of Company Resources For The Development Of Process Technology." *International Journal of Innovation Management* 06(02), 105–30.
Lager, T.,, Rennard, J.P., (2014). "Managing the Manufacturing - R&D Interface: An Extended Editorial Viewpoint." *Journal of Manufacturing Technology Management* 25(2), 146–54.
Leczo, T. (2009). "HIsmelt{reg_sign} Technology: The Future of Ironmaking." *Iron and Steel Technology* 6(3), 1-10.
Lee, S., Park, Y. (2005). Customization of technology roadmaps according to roadmapping purposes: Overall process and detailed modules. *Technological Forecasting and Social Change*, 72(5), 567-583.
Mahdiraji, H.A., Zavadskas, E.K., Kazeminia, A., Abbasi Kamardi, A.A., (2019). "Marketing Strategies Evaluation Based on Big Data Analysis: A Clustering-MCDM Approach." *Economic Research-Ekonomska Istraživanja* 32(1):2882–98.
Mahdiraji, H., Arabzadeh, M., Ghaffari, R. (2012). Supply chain quality management. *Management Science Letters*, *2*(7), 2463-2472.
Mahdiraji, H.A., Govindan, K., Zavadskas, E.K., Razavi Hajiagha, S.H. (2014). Coalition or decentralization: a game-theoretic analysis of a three-echelon supply chain network. *Journal of Business Economics and Management*, *15*(3), 460-485.
Mahdiraji, H.A., Kazimieras, E., Razavi, S.H., (2015). Game-theoretic approach for coordinating unlimited multi-echelon supply chains. *Transformations in Business & Economics*, *14*(2), 35.
Mahmoudi, M., Amoozad Mahdiraji, H., Jafarnejad, A., Safari, H., (2019). Dynamic prioritization of equipment and critical failure modes: An interval-valued intuitionistic fuzzy condition-based model. *Kybernetes*.
McAdam, R., Bititci, U., & Galbraith, B. (2017). Technology alignment and business strategy: A performance measurement and dynamic capability perspective. *International Journal of Production Research*, *55*(23), 7168-7186.
Milgrom, P,, Roberts, J., (1995). "Complementarities and Fit. Strategy, Structure in Manufacturing." *Journal of Accounting and Economics* 19(2–3),179–208.
Mokhtarzadeh, N., Mahdiraji, H., Beheshti, M., Zavadskas, E. (2018). A Novel Hybrid Approach for Technology Selection in the Information Technology Industry. *Technologies*, *6*(1), 34-54.
Mohammadi, M., Rezaei, J., (2019). "Bayesian Best-Worst Method: A Probabilistic Group Decision Making Model." *Omega* 102075.
Mou, Q., Zeshui, X., Huchang, L., (2016). "An Intuitionistic Fuzzy Multiplicative Best-Worst Method for Multi-Criteria Group Decision Making." *Information Sciences* 374, 224–239.
Myrodia, A., Moseley, A., & Hvam, L. (2017, December). Product portfolio optimization based on substitution. In *2017 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)* (pp. 1651-1655). IEEE.
Nair, A., & Dreyfus, D. (2018). Technology alignment in the presence of regulatory changes: The case of meaningful use of information technology in healthcare. *International journal of medical informatics*, *110*, 42-51.
Phaal, R., Farrukh, C.J., Probert, D.R., (2004). Technology roadmapping—a planning framework for evolution and revolution. *Technological forecasting and social change*, 71(1-

2), 5-26.
Pereira, H. 2007. *Cork: Biology, Production, and Uses,* Elsevier.
Pisano, G.P., Wheelwright, S.C., (1995). The new logic of high-tech R & D. *Long Range Planning*, *28*(6), 128-128.
Potstada, M., Parandian, A., Robinson, D.K., Zybura, J. (2016). An alignment approach for an industry in the making: DIGINOVA and the case of digital fabrication. *Technological Forecasting and Social Change*, *102*, 182-192.
Ramundo, L., Taisch, M., & Terzi, S. (2016, September). State of the art of technology in the food sector value chain towards the IoT. In *2016 IEEE 2nd International Forum on Research and Technologies for Society and Industry Leveraging a better tomorrow (RTSI)* (pp. 1-6). IEEE.
Razavi Hajiagha, S.H., Mahdiraji, H.A., Hashemi, S.S., Turskis, Z. (2015). Determining weights of fuzzy attributes for multi-attribute decision-making problems based on the consensus of expert opinions. *Technological and Economic Development of Economy*, *21*(5), 738-755.
Reichstein, T., Salter, A., (2006). "Investigating the Sources of Process Innovation among UK Manufacturing Firms. Industrial and Corporate Change 15(4), 653-682." *Academic.Oup.Com*.
Rezaei, J., (2015). "Best-Worst Multi-Criteria Decision-Making Method." *Omega* 53, 49–57.
Rezaei, J., (2016). "Best-Worst Multi-Criteria Decision-Making Method: Some Properties and a Linear Model." *Omega* 64,126–30.
Rezaei, M., Jafari-Sadeghi, V., Bresciani, S., (2020) What Drives the Process of Knowledge Management in a Cross-Cultural Setting: The Impact of Social Capital, *European Business Review*. doi: 10.1108/EBR-06-2019-0127
Rösiö, C., Bruch, J., (2018). "Exploring the Design Process of Reconfigurable Industrial Production Systems Activities, Challenges, and Tactics." *Journal of Manufacturing Technology Management* 29(1), 85–103.
Sadeghi, A., Alem-Tabriz, A., Zandieh, M. (2011). Product portfolio planning: a metaheuristic-based simulated annealing algorithm. *International Journal of Production Research*, *49*(8), 2327-2350.
Sadeghi, A., & Zandieh, M. (2011). A game theory-based model for product portfolio management in a competitive market. *Expert Systems with Applications*, *38*(7), 7919-7923.
Stacey, G.S., & Ashton, W.B. (1990). A structured approach to corporate technology strategy. *International Journal of Technology Management*, *5*(4), 389-407.
Trott, Paul. (2010). *Innovation Management and New Product Development, 5th Edition*. Pearson education.
Wang, J.Q., Cao, Y.X., & Zhang, H. Y. (2017). Multi-criteria decision-making method based on distance measure and Choquet integral for linguistic Z-numbers. Cognitive Computation, 9(6), 827- 842.
Webster, A., Gardner, J., (2019). Aligning technology and institutional readiness: the adoption of innovation, *Technology Analysis & Strategic Management*, 31(10), 1229-1241.
Zhang, Y., Jiao, J., (2005). "Product Portfolio Identification Based on Association Rule Mining." *CAD Computer-Aided Design* 37(2):149–72.